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INDUSTRIAL EFFICIENCY.

THE BEARINGS OF PHYSIOLOGICAL SCIENCE THEREON: A REVIEW OF RECENT WORK.

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One of the most striking features of the present war is the unprecedented use that is being made of science. In all directions one sees the laboratories called upon to direct their past discoveries and their present powers toward the devising of ways in which best to achieve the ends of the warring nations, and the men of the laboratories called upon for experimentation, for counsel, and for the guidance of the various units of the vast forces employed. This is so not only at the front where the multitudinous death-dealing and death-defying devices daily and nightly proclaim the supremacy of science, but back in the hospitals where the dying are saved from death, in the camps where the living are made fit for fighting, in the factories where the instruments of war are being rapidly produced, and even in the homes of the people where training in scientific living is being attempted on a gigantic scale. It seems impossible that this wide recognition of the utilitarian value of science and this eagerness to utilize its achievements shall altogether cease when the horrors have ended and the possibility of peaceful living returns. With the new ways of thinking and of living that are now being learned, mankind will probably continue to demand, and the laboratories will certainly continue to discover, even more efficient ways, and it seems inevitable that science will continue to maintain its proud place among the leading factors of human progress.

Industry has never been backward in accepting and utilizing scientific discoveries. Once they have been shown to be of real value in increasing the output, decreasing the cost, or improving the quality of the product, they are quickly adopted and made a part of industrial processes. Industry does not merely wait for outside contributions, but maintains its own laboratories, often upon a large scale and manned by able men, and thus scientific research has become one of its prominent features. The phenomenal industrial advances of recent decades have been due chiefly to the achievements of two sciences—mechanical engineering, which has invented and developed automatic machinery, and chemistry, which has discovered new chemical substances and new chemical processes.

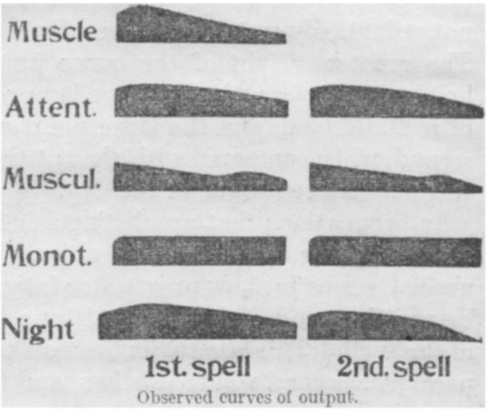
But all this great progress in improving industrial work on its physical side has not yet succeeded in eliminating the human being. Men and women are as necessary as ever to the performance of industrial work, however much their occupations may have been changed, and one of the great problems with which industry still has to deal is that of discovering how this human element must be utilized in order to secure its greatest efficiency and obtain from it its greatest value to the employer. Industrial medicine and sanitation have been making marked headway; efficiency engineering, or scientific management, has devised methods that under proper direction have proved valuable; and no one can dispute the fact that these agencies have contributed a considerable share in making the human factor in industrialism more effective. But none has solved the problem, and in recent years it has become gradually clearer that much light can here be derived from physiological science and that a new application of physiological principles—an industrial physiology, if one desires a specific title—has been gradually appearing.

From the standpoint of industrial physiology the industrial worker is looked upon as bringing to the general physical equipment of the factory his own bodily machine, the most intricate of all the machines used in the plant. This machine must be understood, it must be constantly watched, it must be used intelligently, and it must not be abused. Like other industrial machines it can be worked at different speeds, but unlike other industrial machines it can not be worked for an indefinite period, because it is subject to the limitation of fatigue. Fatigue delays work, diminishes output, spoils goods, causes accidents and sickness, keeps workers at home, and in all these ways is an obstacle to efficiency. How fatigue can be kept down to its lowest reasonable limit, how the working power of the individual can be maintained from day to day and from week to week and be made to yield a maximum output without detriment to itself and to others—in other words, how the human machine can be used so as to obtain from it the most profit—constitutes one of the great industrial problems of the day.

Much light had already been thrown upon the solution of this problem before the war began to make its unprecedented demands on industrialism, but progress has been much more rapid since the fateful month of August of three years ago. Various individual efforts to investigate industrialism from the physiological standpoint have now by common consent centered in Great Britain in the Health of Munition Workers Committee and in America in the Committee on Industrial Fatigue of the Advisory Commission of the Council of National

Defense, associated with the Public Health Service. These two bodies have been actively engaged in studying war industries, and the results of this study, not yet ended, are already beginning to have an important, and will, it is hoped, continue to have a lasting, influence on the industrial work of the world.

The American committee has been making a study of the hourly output of individual workers throughout the working shift. Their observations, which have been carried out under the immediate direction of Mr. P. Sargant Florence, who was formerly connected with the British investigations, when combined with previous results obtained by him and others, show that the course of output follows certain definite lines, which differ in different kinds of occupation and constitute more or less distinct types. These may be represented by typical curves. The study is not yet completed, and the curves so far obtained can not be regarded as necessarily final, nor do they necessarily comprise all possible types. They are therefore presented here as tentative and suggestive.



Observed curves of output.

When in a familiar experiment of the physiological laboratory a single muscle of an animal is stimulated for a considerable period by a regular series of slight electric shocks and is made to contract with each stimulus, and with each contraction to lift a given load, the work performed in the successive contractions from the beginning to the end may be regarded as a curve which, while differing in details, is perfectly typical of all muscles (see figure). The greatest amount of work is not performed at the beginning of the working period, but the curve at first rises gradually to a maximum, indicating for a time a progressive improvement in working power. This rise is still usually called by the original name given to it, the "treppe," or "staircase." Following the maximum, there is a gradual slow decline in the curve, indicating fatigue, which may continue until the muscle is completely exhausted and totally unable to lift the load. The treppe and the fatigue are typical normal phenomena. This curve of the work of a single muscle may well be kept in mind in considering the curves of output of the industrial worker in a working spell. It should be understood, however, that in the human being the physiological conditions are infinitely more complicated than in a single muscle, for there are added the many other organs of the body whose functions may possibly modify muscular work, and especially the nervous system, with all its possibilities of wilfully changing an output curve that might otherwise represent genuine capacity. In the output curve of the human being a rise may signify, not an involuntary treppe, but a voluntary spurt; and a fall may signify, not real fatigue, but a voluntary restriction of effort. It is not always easy, and it may often prove impossible, to distinguish between the involuntary and the voluntary phenomena.

A curve of output that closely resembles the muscle curve has been found in work that requires close attention and exact muscle coordination. There is at first a gradual rise, continuing through the first hour or two, then a fall gradually increasing throughout the remainder of the working spell. After the luncheon hour the general form of the curve is repeated, but with slight changes in detail. The rise in each spell is often called the "practice effect," although it is analogous to the treppe of the muscle curve; the fall, if the work is not voluntarily restricted, is usually interpreted as indicating fatigue. The greater height of the curve just after, as compared with its height just before, the luncheon hour represents the restorative effect of rest and food; and the lower point of the curve at the end of the second, when compared with that at the end of the first spell, signifies the cumulative fatigue of the day.

In occupations that are distinguished especially by their muscular character, the output curve, although more observations are here needed, seems to show progressive fatigue, but the practice effect may be wanting, and a rise followed by a fall, appears in the latter half of the spell. This late rise indicates a temporary inhibition of fatigue, perhaps a second wind; it is less, and fatigue is more, marked in the second spell.

Where work is monotonous and where it is frequently broken by natural pauses, a curve may be obtained which for both working spells is nearly a straight and horizontal line, showing a slight practice effect but no fatigue.

The American committee has found instances of another type of output, in which the figures of the total daily production by the individual from day to day, and even from week to week, show a striking uniformity, and the inference seems to be justified that the workers are not working to their full capacity but, either voluntarily or involuntarily, have fixed upon a certain quantitative output as appropriate to a day's work. No generalized form of curve for such a method of working can yet be presented, but individual curves show usually an early fall with often a marked spurt before the close of the spell. To what degree fatigue enters into the work here is difficult to decide without further study. The frequently pronounced spurt following a decrease in production, is evidently due to the recognition by the worker that unless he bestirs himself his stint will not be finished by closing-time. The fact that a pronounçed spurt is possible indicates that capacity had not before been reached. If work is actually stopped for a portion of the spell for any unusual reason, such as the breakdown of the machinery, there is a rush to accomplish the conventional amount before the end, and this often succeeds. This direct limitation, or, as Florence calls it, "stereotyping" of output, might be expected where wages are paid by the day, but it is found even where piece rates prevail and the worker is free to earn more by doing more. Its cause is probably complex and many elements may enter into it—the unthinking recognition that a certain amount is enough for a day's work; the fear, often justified, that if more is accomplished piece rates will be cut; the disinclination of many rapid workers to surpass their fellows; unwillingness or inability of the foreman to drive until individual capacity is reached; the realization by the foreman that if individual capacity is reached his department will soon exhaust all its available stock; and, last but not least, in many cases just plain human laziness. Overdriving has long been recognized as one of the evils of industrial work, but less attention has been given to underdriving. It seems reasonable that individual capacity should be among the first factors to be considered in determining the standard of output. The prevalence and causes of a maintenance of output on a stereotyped level far below the limit of individual capacity would well repay careful study.

Which, if any, of the various curves of output that have been presented represents the ideal that should always be striven for can not now be stated. Here experiment is needed. Where a genuine fatigue fall in the curve is pronounced, the cessation of work is obviously indicated. This may take the form, as circumstances may indicate, of either an intermediate recess period or the shortening of the hours spent at the factory.

This brings us to one of the most obvious problems of industrial physiology: viz. that of the duration of daily and weekly labor. At the beginning of the war, along with other evidences of the feverish haste which characterized the nation's activities, the duration of labor in the munition factories of Great Briatain was greatly increased. Besides lengthening the regular daily schedule, overtime and Sunday labor were frequently resorted to. In America, following the lead of the Council of National Defense, hours that had already been established by custom or law have in general been maintained, and unusually prolonged labor has been avoided in most factories. The result of the long British hours is what might have been predicted, the production of excessive fatigue; in America excessive fatigue seems so far to be less pronounced.

It is widely believed, and especially by employers of labor, that longer hours mean necessarily a greater output. If industrial physiology does nothing else but show the fallacy of this notion, it will have justified itself. A man can of course accomplish more in two hours than in one hour, but it does not follow that he can accomplish more in 15 hours than in 12, or more in 12 than in 10, or even more in 10 than in 8 hours. Here the American Committee has discovered a strikingly suggestive fact in the night work of one of our large munition factories, the duration of the night shift being 12 hours. After 5 a. m. the curve of output shows a rapid decline, and during the last 40 minutes there is very little or absolutely no production. The elimination of the last two hours would be greatly to the advantage of the men and would probably result in no diminution but an actual increase in the total product turned out. Under the British Committee, Vernon has accumulated most striking statistical evidence of the beneficial results of a reduction of the hours of labor. Two instances will suffice to illustrate the point: With a group of 80 to 100 women turning aluminum fuse bodies the reduction of the weekly hours of actual work from 66.2 to 45.6, a saving of more than 20 hours, increased the gross production by 9 per cent. When the actual weekly working hours of 56 men engaged in the very heavy labor of sizing fuse bodies were reduced from 58.2 to 51.2, the gross output was increased by 21 per cent.

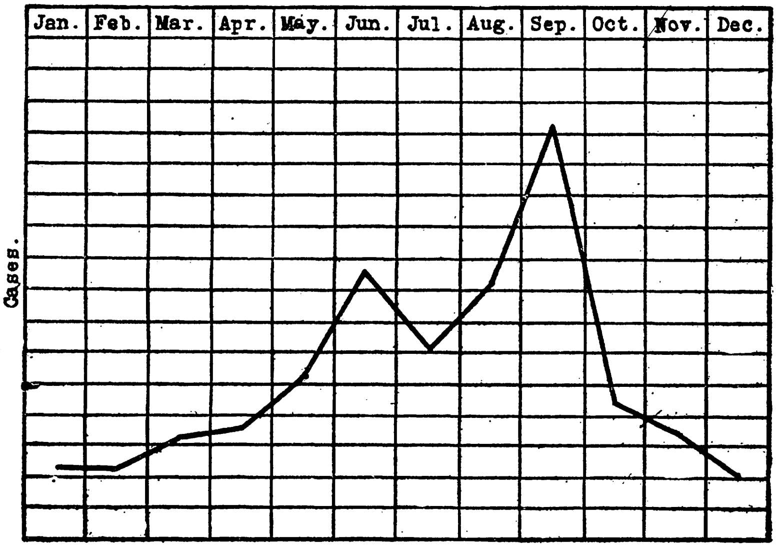
It is impossible in the time here allowed to go further into detail in the bearings of physiological science on industrial efficiency. Industrial physiology tells us, in the interest of a large output, not only to keep the hours of labor down to what experience has shown to be a reasonable limit, but to choose this limit in accordance with the fatiguing effects of the different specific occupations. It tells us to introduce recess periods into long spells, to omit Sunday labor, and to impose overtime on already fatigued workers only in rare emergencies and when compensation can be given by free hours later. It tells us not to keep the same workers continually on the night shift, but to alternate night with day work. It tells us that each worker and each task possesses a specific standard of strength, and it indicates in what task each worker will probably prove most efficient. It tells us that each worker has a rhythm that is best adapted to his own neuromuscular mechanism and that it is advantageous to place in a squad of workers doing a specific task only those possessing similar rhythms, eliminating the faster and the slower individuals, and then to adjust the speed of operation to the common rate. Such instances as these few reveal the scope of industrial physiology and show how it is indicating some of the ways in which the most intricate of all industrial machines, the body of the worker, must be used in order to bring out its greatest usefulness.

Our Government is now rapidly making contracts for war goods of all kinds. Our factories, heretofore engaged largely on foreign orders, are now turning eagerly to the work required to maintain and equip our own forces. Now is the appropriate time to place this work upon a scientific basis and in accord with the principles of industrial physiology. I am sure that if such facts as I have been able only briefly here to present could be understood in all their significance by our producers of war supplies, the end of this latest and most terrible world struggle would be hastened.

MALARIA IN SOUTH CAROLINA.

PREVALENCE AND GEOGRAPHIC DISTRIBUTION, 1915 AND 1916.

The study of the prevalence and geographic distribution of malaria in the State of South Carolina was begun in 1913. Previous reports on this subject were published in the Public Health Reports of March 13, 1914, and May 28, 1915, and issued as reprints Nos. 172 and 277.



Relative prevalence of malaria in South Carolina, by months, as indicated by the number of cases reported.

The physicians were circularized every three months during the calendar year 1915, and during the first, second, and fourth quarters of the year 1916, reply postal cards being used for the purpose.

Of the cards sent to the physicians, a little more than 12.5 per cent were returned. The number of cards sent out, the number of schedules returned, and the number of counties represented at each circularization are shown in Table 1.